those builds on time. However, as was the case with WiMAX, when a technology is still being developed, technological issues can significantly delay planned deployments. LTE is an example of a new wireless technology that has not been deployed yet commercially on a wide scale so we must be cautious about planned deployment schedules.

As we discuss later in this document these commercial 4G build outs may not fully meet the National Broadband Availability Target without incremental investment; but the commercial investments in these deployments will certainly improve the incremental economics of 4G fixed wireless networks in those areas.

Due to the lack of geographic specificity and overlapping coverage areas we were not able to precisely forecast future wireless coverage speeds that will be available in years to come based on public announcements.

Satellite network upgrades

The capacity of a single satellite will increase dramatically with the next generation of high throughput satellites (HTS) expected to be launched in the next few years. ViaSat Inc., which acquired[18] WildBlue Communications in December 2009, and Hughes Communications Inc. plan to launch HTS in 2011 and 2012, respectively.[19, 20] These satellites each will have a total capacity of more than 100 Gbps, with some designated for upstream and some for downstream. After the launch of the new satellites, ViaSat expects to offer 2-10 Mbps downstream while Hughes suggests it will offer advertised download speeds in the 5-25 Mbps range.[21] Despite this additional capacity, our analysis suggests it will be insufficient to address more than 3.5% of the unserved. See Chapter 4 on satellite.

Conclusion

While such investments in technology and broadband networks may help bring faster speeds to those who are already served, and could potentially reduce the average cost per subscriber, it is far from certain that they will decrease the number of unserved.

Exhibit 2-N: Publicly Announced 4G Wireless Deployments

Technology	Companies	2009	2010	2011	By 2013
LTE	• Verizon • AT&T • MetroPCS • Cox		• Verizon (100MM) • AT&T (Trials)	• AT&T (start deployment) • Cox (start deployment) • MetroPCS (start deployment)	• Verizon (entire network)
WiMAX	• Clearwire • Open Range • Small WISPs	• Clearwire (30MM) • WISPs (2MM)	• Clearwire (120MM)		• Open Range (6MM)

Exhibit 2-O: Specific Company Historical Performance Against Announced Completion Dates

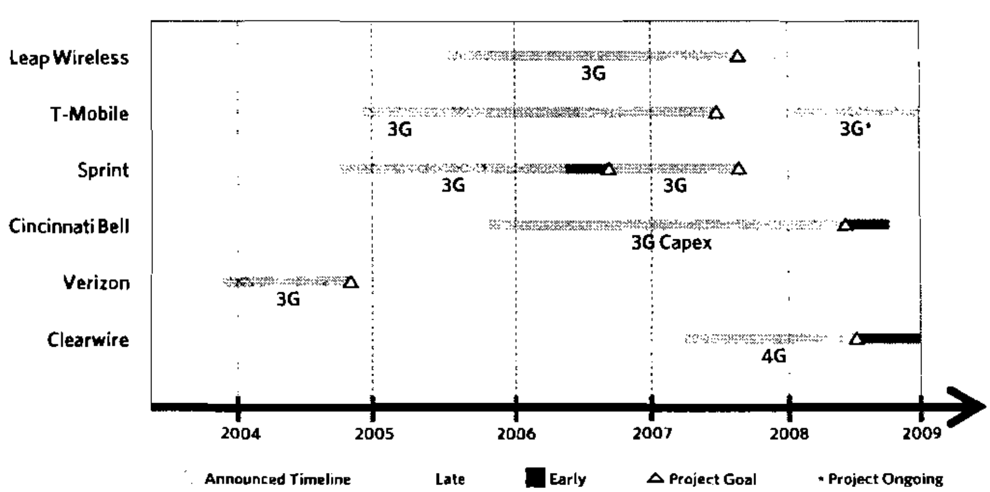


Exhibit 2-P: Publicly Announced Total Near Term Satellite Broadband Capacity[22]

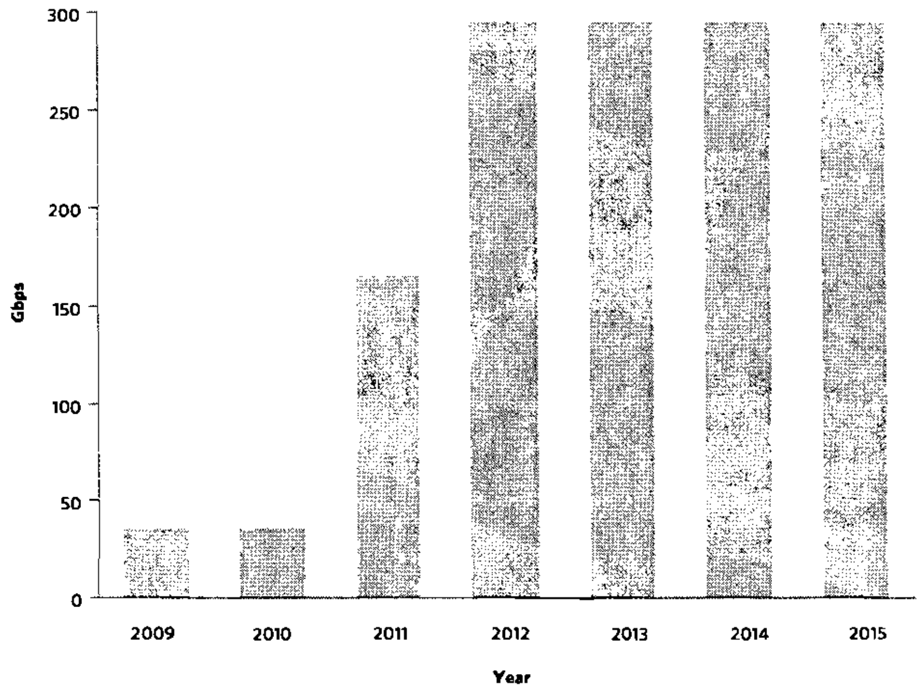


Exhibit 2-Q: Commercial Data Sources Used to Calculate Availability

Vendor	Database	Use
American Roamer	Advanced Services	Wireless service footprint
Geolytics	2009 block estimates	Block level census estimates
	Estimates professional	Block group level estimates
GeoResults	National Business Database	Fiber served building (flag); business locations and demographics
GeoTel(imap)	MetroFiber	Metro Fiber Routes (GDT and Navteq)
	LATA Boundaries	Used for middle mile map to group switches into latas
	Fiber Lit Buildings (point)	Used to flag wire center boundaries as likely having fiber infrastructure
Telcordia	LERG	Switch office locations
TeleAtlas	Wire center boundaries	Wire center boundaries, domswitch, OCN, carrier name
	Zip code boundaries	Zip code boundaries
Tower Maps		Location of towers and sites
Warren Media	Warren Media	Cable-franchise boundary (by block group)

Exhibit 2-R:
Public Data Sources Used to Calculate Availability

Data Source	Database	Location
Alabama	State broadband availability	http://www.connectingalabama.com/ca/maps.aspx <http://www.connectingalabama.com/ca/maps/CBResults072909.zip>
California	State broadband availability	ftp://ftp.cpuc.ca.gov/Telco/Existing_Broadband_Service_Aggregated_072409.zip
Pennsylvania	State broadband availability	Available from Technology Investment Office
Minnesota	State broadband availability	Available from Technology Investment Office
Wyoming	State broadband availability	Available from State CIO
US Census	Tiger 2008	Blocks, Counties, Roads, Block Group Boundaries
	SF1	Summary File 1, US Census 2000
	SF3	Summary File 3, US Census 2000
FCC	Varies	Market Data Boundaries (adjusted for Census County Updates)
NECA	Tariff 4	PDF as filed 9/2009
Congressional Districts	110 Congress	http://www.nationalatlas.gov/atlasftp.html?openChapters=chpbound#chpbound

CHAPTER 2 ENDNOTES

1 DOCSIS 2.0 is capable of delivering ~10 Mbps, while DOCSIS 3.0 is capable of delivering ~50 Mbps. FTTN and FTTP can offer speeds well over 6 Mbps; however, the statistical-regression methodology used to estimate availability as a function of speed, combined with the source data for that regression, do not allow us to make estimates for telco-based service above 6 Mbps. *See* the Telco portion of this section for more detail.

2 Mid-size carriers include Alaska Communications Systems, CenturyLink, Cincinnati Bell, Citizens Communications, Consolidated Communications, FairPoint Communications, Hawaiian Telecom, Iowa Telecom and Windstream.

3 *See* Exhibit 4-BT for a description of middle versus second mile.

4 The Broadband Data Improvement Act (BDIA), Pub. L. No. 110-385, 122 Stat. 4096 (2008).

5 *See* Exhibits 2-Q and 2-R for a complete list of licensed data that we used.

6 *See* Warren Media MediaPrints database, http://www.mediaprints.com/index.htm (accessed Aug. 2009) (on file with the FCC) (Warren Media database).

7 *See* Warren Media MediaPrints database.

8 ROBERT C. ATKINSON & IVY E. SCHULTZ, COLUMBIA INSTITUTE FOR TELE-INFORMATION, BROADBAND IN AMERICA: WHERE IT IS AND WHERE IT IS GOING (ACCORDING TO BROADBAND SERVICE PROVIDERS) at 57 (2009) ("CITI BROADBAND REPORT"), available at http://www4.gsb.columbia.edu/citi/.

9 Massachusetts General Laws Chapter 166A § 4 states, in part: "each applicant shall set forth as completely as possible the equipment to be employed, the routes of the wires and cables, the area or areas to be served." Upon its own investigation (Investigation of the Cable Television Division of the Department of Telecommunications and Energy on its Own Motion to Review the Form 100, CTV 03-3, November 30, 2004), the department (which became known as the "Department of Telecommunications and Cable" in April 2007) found, in part, at pages 18-19, that the statutory requirement referred to above is meant to promote "general use," and finds that "a strand map identifying the presence and location of the cable system within a specific community is sufficient to satisfy the statutory requirement." This order also finds that an issuing authority (a municipality) may request more detailed, technical information about a cable system than the cable plant map is required for general use, provided it is willing to enter into a non-disclosure agreement with the cable operator if requested.

10 Infrastructure data were not accessed by the FCC directly but were analyzed for the FCC by a contractor with access to these data.

11 The Broadband Data Improvement Act (BDIA), Pub. L. No. 110-385, 122 Stat. 4096 (2008).

12 American Recovery and Reinvestment Act of 2009, Pub.L. No. 111-5, § 6001(k)(2)(D), 123 Stat. 115, 516 (2009) (Recovery Act).

13 CITI BROADBAND REPORT AT 7.

14 CITI BROADBAND REPORT AT 7.

15 CITI BROADBAND REPORT AT 7.

16 T. McElgunn, "DOCSIS 3.0 Deployment Forecast," Pike & Fischer, 2009.

17 CITI BROADBAND REPORT AT 8.

18 On October 1, 2009, ViaSat announced it had signed a definitive agreement to acquire privately held WildBlue. On December 15, 2009, ViaSat announced the completion of the announced acquisition; see ViaSat, WildBlue Communications Acquisition Closes, http://www.viasat.com/news/wildblue-communications-acquisition-closes (last visited Feb. 12, 2010).

19 Letter from Mark Dankberg, Chairman & CEO, ViaSat, to Blair Levin, Executive Director of OBI, FCC, GN Docket Nos. 09-47, 09-51, 09-137 (Jan. 5, 2010) ("ViaSat Jan. 5, 2010 Ex Parte") at 2.

20 Letter from Stephen D. Baruch, Counsel for Hughes Communications, Inc., to Marlene H. Dortch, Secretary, FCC (Oct. 26, 2009) ("Hughes Oct. 26, 2009 Ex Parte") at 6.

21 CITI BROADBAND REPORT AT 57.

22 Note that this forecast only includes publicly announced launches and not additional, planned launches that are likely. *See* Northern Sky Research, How Much HTS Capacity is Enough? (2009), http://www.nsr.com/AboutUs/PressRoom.html (last visited Jan. 20, 2010).

III. CALCULATING THE INVESTMENT GAP

To calculate the amount of money required to offer service in areas that would otherwise remain unserved, we must make a number of decisions about how to approach the problem, design an analysis that accurately models the problem and make a number of assumptions to conduct the analysis. To this end, we created an economic model to calculate the lowest amount of external support needed to induce operators to deploy broadband networks that meet the National Broadband Availability Target in all unserved areas of the country.

KEY PRINCIPLES

The FCC developed its broadband economic model to calculate the gap between likely commercial deployments and the funding needed to ensure universal broadband access. Underlying the model's construction are a number of principles that guided its design.

- **Only profitable business cases will induce incremental network investments.**
- **Investment decisions are made on the incremental value they generate.**
- **Capturing the local (dis-)economics of scale that drive local profitability requires granular calculations of costs and revenues.**
- **Network-deployment decisions reflect service-area economies of scale.**
- **Technologies must be commercially deployable to be considered part of the solution set.**

Only profitable business cases will induce incremental network investments. *Private capital will only be available to fund investments in broadband networks where it is possible to earn returns in excess of the cost of capital. In short, only profitable networks will attract the investment required. Cost, while a significant driver of profitability, is not sufficient to measure the attractiveness of a given build; rather, the best measure of profitability is the net present value (NPV) of a build. This gap to profitability in unserved areas is called the Broadband Availability Gap in the NBP; throughout this paper, we will refer to this financial measure as the Investment Gap.*

The calculation of the $23.5 billion Investment Gap is based on the assumption that the government will not own or operate the network itself, but rather will provide funding to induce private firms to invest in deploying broadband. This is primarily because private firms can provide broadband access more efficiently and effectively due to their ownership of complementary assets and experience in operating networks. By subsidizing only a portion of the costs, the government provides the markets with the incentive to continue to innovate and improve the efficiency of buildouts and operations. In addition, since private firms will be investing a significant portion of the costs, the amount of public money required is greatly reduced.

Simply calculating the incremental costs of deploying broadband is not enough to determine the Broadband Investment Gap necessary to encourage operators to deploy. To ensure that firms seeking an adequate return on their invested capital will build broadband networks in unprofitable areas, we solve for the amount of support necessary to cause the networks' economics to not only be positive, but to be sufficiently positive to motivate investment given capital scarcity and returns offered by alternative investments.

The model assumes an 11.25% discount rate; by calculating the NPV gap as the point where NPV = 0, we equivalently set the internal rate of return (IRR) of these incremental broadband buildouts to 11.25%. This rate is the same one determined by the FCC in 1990 to be an appropriate rate for telecom carriers earning a rate of return on interstate operations.[1]

In order to determine the level of support needed to encourage operators to build broadband networks, we identify the expected cash flows associated with building and operating a network over the project's lifetime of 20 years. Next, we compute the NPV of those cash flows to arrive at the Investment Gap. In other words, the gap is the present value of the amount by which operators fail to produce an 11.25% IRR. It is important to note that ongoing expenses include incremental deployment and operational costs (initial capex, ongoing and replacement capex, opex, SG&A) as well as depreciation, cost of money and tax components for an incremental broadband investment; revenues include all incremental revenue from the modeled network with average revenue per user (ARPU) and take rates calculated as discussed below. As a result, when the NPV analysis yields a value of zero, it means that the project's revenues are sufficient to cover all expenses while providing a rate of return on invested capital of 11.25%.

In fact, if a carrier has a weighted-average cost of capital (WACC) above the 11.25% rate, even a guarantee to reach the 11.25% IRR would not cause it to build.

In contrast, if a carrier has a WACC lower than 11.25%, it will earn profits above the 11.25% IRR proportional to the size of the spread between WACC and discount rate. Having the IRR above WACC does not necessarily mean that operators are earning outsize returns, however. Since the support level is based on forecasts of both revenue and cost across the lifetime of the asset, carriers are taking on significant risk by investing or committing to invest in network maintenance and operations. The extent to which IRR provides returns in excess of WACC reflects the operational risk of providing service in unserved areas, where the economics are generally unfavorable. Service providers are likely to have other investment opportunities with strong risk-return profiles at their WACCs.

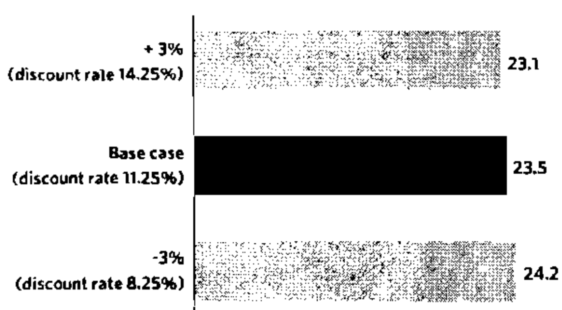
One result of this execution risk is that carriers with WACC below the 11.25% discount rate might tend to favor a guaranteed annuity over time that would lock in the 11.25% return. Receiving support as an upfront payment, either in whole or in part, would require the operator to take on this higher execution risk, making the investment potentially less attractive.

After receiving the one-time payment, the telecom operators can reinvest the funds in their operations. Investments that yield a return above 11.25% will result in an economic benefit to the telecom provider.

Since the operators in any specific area, their associated WACCs and the disbursement mechanism are all unknown at this point, we make the simplifying assumption that carriers will be indifferent to receiving an upfront one-time payment, a series of payments over time or a combination of the two.

While the discount rate typically has significant impact on the NPV of a project, in this case the impact is mitigated for two main reasons. First, initial capital expenditures, which take place at the start of the project and, therefore, are not discounted, account for 65.1% of the Broadband Investment Gap. Second, because revenue and ongoing costs offset one another to a large extent (see Exhibit 1-A), the impact of changes in the discount rate is small. As shown in Exhibit 3-A, even significant changes in the discount rate (of up to 300 basis points) yield modest changes in the base-case Investment Gap of less than $1 billion.

Exhibit 3-A:
Impact of Discount Rate on Investment Gap



Time horizon for calculations

Calculating the value of long-life investments such as fiber builds or cell-site construction requires taking one of two approaches: explicitly forecasting and modeling over the entire useful life of the asset, or calculating either the salvage value of remaining assets or the terminal value of operations. Although neither choice is optimal, we use a 20-year explicit model period, which corresponds to the long-life assets in broadband networks. We do not include any terminal or salvage value at the end of a shorter explicit forecast period.

Calculating the ongoing terminal value of operations in this context is challenging at best since the modeled cash flows never reach a steady state. As we note below, when describing key assumptions, the take rate grows across the entire calculation period, and levelized take rate for a five- or 10-year forecast dramatically understates the final take rate. The result is that a terminal value calculation will not accurately reflect the ongoing value generated by the investment. Consequently, we must explicitly model over the full 20-year life of the network assets. Although utilizing a 20-year forecast is not atypical for businesses making capital planning decisions, such forecasts obviously require making speculative long-range assumptions about the evolution of costs and revenues.

It is also worth noting that the calculation models the value of an incremental broadband network investment, not the value of the company. Consequently, we assume that at the end of the 20-year explicit period there is no substantial value remaining for two reasons. First, from the accounting perspective—and based on an estimate of actual useful life[2]—most of the assets have been fully depreciated, and those that have some value remaining only have value in a fully operating network. Second, from a technological perspective, it is unclear that there will be any incremental value from the existing 20-year-old network relative to a greenfield build.

Investment decisions are made on the incremental value they generate. *While firms seek to maximize their overall profitability, investment decisions are evaluated based on the incremental value they provide. In some instances, existing assets reduce the costs of deployment in a given area. The profitability of any build needs to reflect these potential savings, while including only incremental revenue associated with the new network buildout.*

The model takes existing infrastructure into account and only calculates the incremental costs and incremental revenues of deploying broadband. This means that in most areas the costs of offering broadband are the costs associated with upgrading the existing telco, cable or wireless network to offer broadband. Exhibit 3-B illustrates the incremental buildout for a telco network. This minimizes support and is consistent with how firms typically view the sunk costs of existing infrastructure.

The full cost of the network is necessary only in areas that require a greenfield build, i.e. in areas with a complete lack of infrastructure or when the greenfield build of one technology has a lower investment gap than upgrading an existing network. Revenues are treated the same way as costs. Only the incremental revenues associated with new services are used to offset costs in the calculation of the gap.

For example, millions of homes are already "wired" by a telephone network with twisted pair copper lines that provide voice telephony service. These telephone networks require only incremental investments to handle digital communications signals capable of providing broadcast video, broadband data services and advanced telephony. Incremental costs of upgrading these networks include investments in: fiber optic cable and optic/electronics in large portions of the copper plant, the replacement and redesign of copper distribution architecture within communities to shorten the copper loops between homes and telephone exchanges, the deployment of new equipment in the exchanges and homes to support high capacity demands of broadband, and sophisticated network management and control systems. The incremental revenues are the revenues associated with the newly enabled broadband and video services.

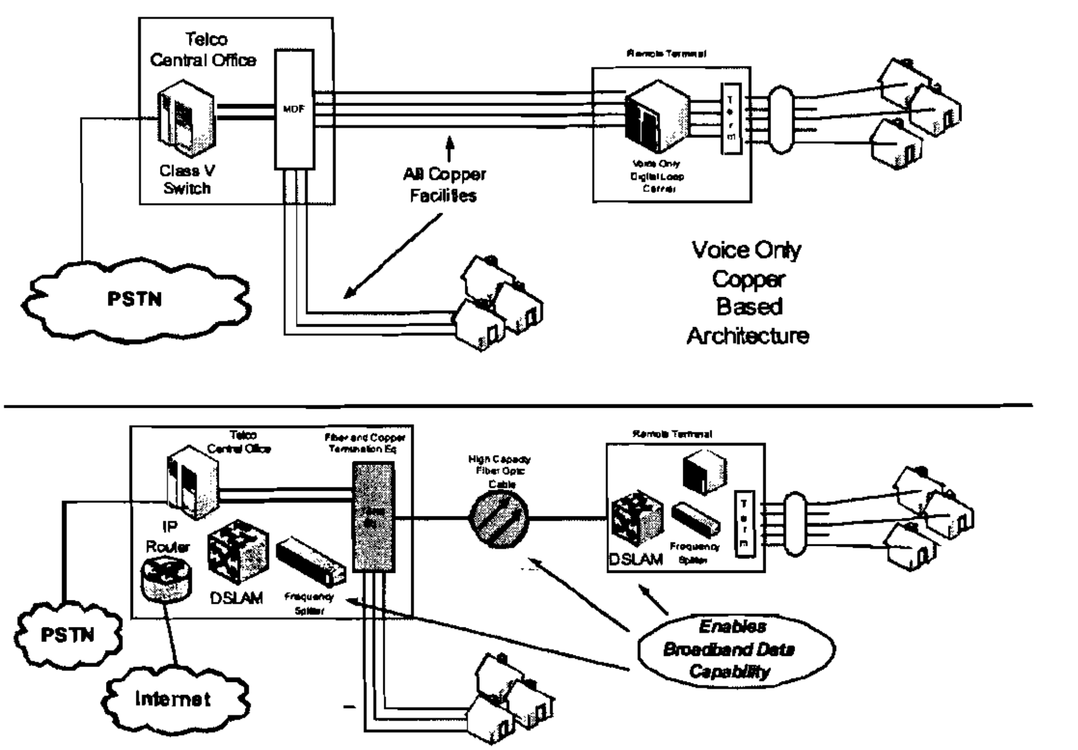
One issue with this approach is that it assumes that existing networks will be available on an ongoing basis. To the extent that existing networks depend on public support, such as USF disbursements, the total gap for providing service in unserved areas could be significantly higher than the incremental calculation indicates.

For the purposes of the financial model, we consider only incremental revenue, which is the product of two main components: the number of incremental customers and ARPU.

The number of incremental customers is based on the technology that is ultimately implemented. Throughout the modeling process, we take care to not "double-count" revenues for operators who upgrade their existing networks with broadband data or video capabilities. For example, if an incumbent telco decides to shorten loop lengths in order to deliver data and video services, only incremental data and video-related revenue should be considered. Incremental revenues from voice products will not be considered since those products are already being offered. Exhibit 3-C shows which products are considered to be incremental for each technology.

Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues. *Multiple effects, dependent on local conditions, drive up the cost of providing service in areas that*

Exhibit 3-B: Incremental Network Elements Necessary to Upgrade a Telephone Network to Offer Broadband



currently lack broadband: Lower (linear) densities and longer distances drive up the cost of construction while providing fewer customers over whom to amortize costs. At the same time, lower-port-count electronics have higher costs per port. In addition, these lower densities also mean there is less revenue available per mile of outside plant or per covered area.

Using the average cost per household of existing deployments, even when adjusted for differences in population density, presents a risk that costs may be underestimated in rural areas. Even when considering local population and linear densities, costs in many rural markets will be subscale, rendering inaccurate a top-down analysis of average costs. Attempting to calculate profitability without taking these variations into account—for example by extrapolating from cost curves in other areas—would necessarily lead to questionable, or even misleading, conclusions. Therefore, we take a bottom-up approach that provides sufficient geographic and cost-component granularity to accurately capture the true costs of subscale markets.

An example of this is evident when we consider the cost allocation of a digital subscriber line access multiplexer (DSLAM) chassis in an area with very low population density. If only one home is connected to the DSLAM, the entire cost of that DSLAM should be allocated to the home rather than a fraction based on the DSLAM capacity. In order to calculate the costs with this level of accuracy, we need geographic and cost-component granularity throughout. Accounting for granularity with respect to geography is particularly important because so many network costs are distance dependent. Calculations are needed at a fine geographic level; therefore, we model the census block as the basic geographic unit of calculation.[3]

Capturing cost-component granularity is important due to the fixed-cost nature of network deployments. For example, one must capture the costs associated with trenching fiber facilities, which are shared among many end-users, differently than the cost associated with line cards and installation, which may be directly attributed to a given customer. We provide more details about the cost calculations of each technology in Chapter 4.

Network-deployment decisions reflect service-area economies of scale. *Telecom networks are designed to provide service over significant distances, often larger than 5 miles. In addition, carriers need to have sufficient scale, in network operations and support, to provide service efficiently in that local area or market. Given the importance of reach and the value of efficient operations, it can be difficult to evaluate the profitability of an area that is smaller than a local service area.*

Though geographic granularity is important in capturing the real costs associated with providing broadband service in rural and remote areas, it does not make sense to evaluate whether to build a network at the census block level. Rather, the modeling needs to capture deployment decisions made at a larger, aggregated "service area" level.

Using the census blocks as a market is problematic for several reasons. First, telecom infrastructure typically has some efficient scale length associated with it. For wireless, that distance is the cell-site radius; for FTTN or DSL the distance is the maximum loop length.[5] These lengths are typically 1 to 3 miles for twisted pair copper and 2 to 5 miles for wireless towers, and span multiple census blocks. As a result, carriers will make deployment decisions based on larger areas.

From a modeling perspective, evaluation at the census block level is problematic as well. Evaluations of which technology has the lowest investment gap done at the census block level could lead to contiguous census blocks with a patchwork of different technologies that no company would actually build.

Even more problematic is that the cost in any one area is driven in part by the costs of shared infrastructure. For example, the cost of a fiber connecting several new DSLAMs to the local central office is shared among all the census blocks served by those DSLAMs. If wireless were found to be cheaper in one of those census blocks and one, therefore, assumed that one of those DSLAMs would not be deployed, the (allocated) cost of the fiber would increase for all remaining DSLAMs. That could lead to another block where wireless is made cheaper, again increasing the cost of the remaining DSLAMs.

Exhibit 3-C: Incremental Revenue by Product and Network Type

	Data	Voice	Video
Telco 12k	Yes	No	N/A
Telco 5k/3k/FTTP	Yes	No	Yes
Cable[4]	Yes	Yes	Yes
Wireless-Fixed	Yes	Yes	N/A
Wireless-Mobile (Non-4G)	Yes	Yes	N/A
Wireless-Mobile (4G)	No	No	N/A

There is no perfect solution to this problem. If the geography is too big there will be portions that would be more efficiently served by an alternate technology, but if the geography is too small it will be subscale, thereby driving up costs. Although the model is capable of evaluating at any aggregation of census blocks, in order to avoid a patchwork of technologies that are all subscale, we have evaluated the cost of technologies at the county level. Counties appear large enough in most cases to provide the scale benefits but not so large as to inhibit the deployment of the most cost-effective technology.

Note that this geography is also technology neutral since it is not aligned with any network technology's current footprint. No network technology boundaries line up exactly with those of counties. Cable networks are defined by their franchise area; wireless spectrum is auctioned in several different geographies, for example, by cellular market areas; and telco networks operate in study areas, LATAs or wire centers. Since the model is capable of evaluating at any aggregation of census blocks, it is possible to evaluate at more granular levels (where the patchwork problems become more likely) or at more aggregated levels.

Technologies must be commercially deployable to be considered part of the solution set. *Though the economic model is forward looking and technologies continue to evolve, the model only includes technologies that have been shown to be capable of providing carrier-class broadband. While some wireless 4G technologies arguably have not yet met this threshold, successful market tests and public commitments from carriers to their deployment provide some assurance that they will be capable of providing service.*

With the exception of 4G wireless, we only include technologies that are widely deployed and have proven they can deliver broadband. Although network technologies continue to advance, enabling operators to provide more bandwidth over existing infrastructure or to provide new services ever-more-cheaply, the promise surrounding technological innovation often outstrips reality.

To avoid a situation where we assume uncertain, future technological advances are essential to a particular solution—where the solution with the lowest investment gap is reliant on unproven technologies—this analysis focuses on technologies which have been substantially proven in commercial deployments. Over long periods, this may tend to overestimate some costs; however, a significant fraction of deployment costs are insensitive to technology (for example, the cost of trenching) while other costs are technology independent (for example, the cost of a DSLAM chassis would be independent of what type of DSL is being used), meaning that overall impact should be minimal.

One notable exception is our treatment of wireless. Our focus on wireless, whether for fixed or mobile, is on 4G technologies that have only just begun to be deployed commercially. Initial trials and our research with service providers and equipment vendors give us confidence in 4G's ability to provide the stated performance at the stated costs—enough confidence to warrant including 4G in our analysis.[6] In addition, because of the significant advancements of 4G relative to current capabilities and the widespread 4G deployment forecasts, we would run the risk of overstating the Investment Gap significantly if we were to exclude it from our analysis.

As noted in the CITI report[7], a significant fraction of areas served by wireless today are likely to be upgraded to 4G service by wireless operators without external (public) support.

Only one U.S. carrier, Clearwire, has deployed a mobile 4G (WiMAX) network commercially, making it difficult to know how much of the unserved population will be covered by 4G. For our model, we take Verizon's announced build-out as the 4G footprint because Verizon is the only operator that has announced precisely where its 4G builds will take place. Verizon has committed to rolling out 4G to its entire 3G service footprint (including those areas acquired with Alltel). The net result is that we assume 5 million of the 7 million unserved housing units will have access to 4G service (i.e., 5 million housing units are within Verizon Wireless's current 3G footprint, which the company has committed to upgrading to 4G).

No wireless carrier, including Verizon Wireless, has committed to offering service consistent with the National Broadband Availability Target. This uncertainty in the ability of wireless-network deployments to deliver fixed-replacement service points to the need for incremental investment by wireless carriers. Simply put, networks designed for relatively low-bandwidth (typically mobile) applications, potentially lack the cell-site density or network capacity to deliver 4 Mbps downstream, 1 Mbps upstream service.

Our calculations for 4G fixed wireless includes incremental investments sufficient to ensure networks capable of delivery consistent with the National Broadband Availability Target. See the section on wireless in Chapter 4 and the Assumptions discussion later in this chapter for more details.

KEY DECISIONS

Implicit within the $23.5 billion gap are a number of key decisions about how to use the model. These decisions reflect beliefs about the role of government support and the evolution of service in markets that currently lack broadband. In short, these decisions, along with the assumptions that follow, describe how we used the model to create the $23.5 billion base case.

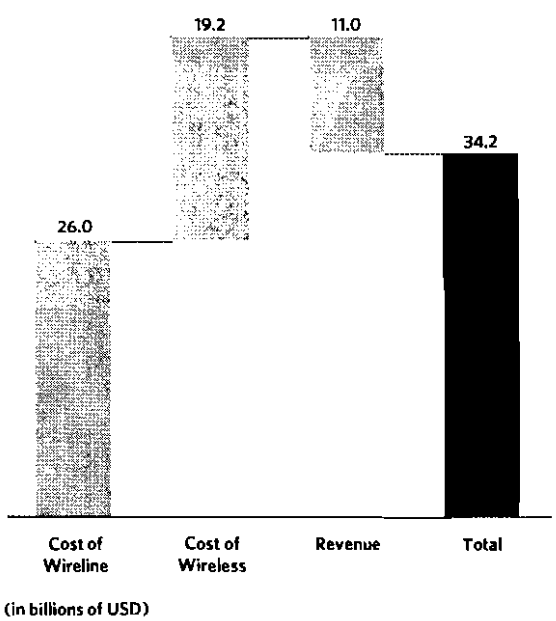
- Fund only one network in each currently unserved geography.
- Capture likely effects of disbursement mechanisms on support levels.
- Focus on terrestrial solutions, but not to the exclusion of satellite-based service.
- Support any technology that meets the network requirements.
- Provide support for networks that deliver proven use cases, not for future-proof buildouts.

Fund only one network in each currently unserved geography. *The focus of this analysis is on areas where not even one network can operate profitably. In order to limit the amount of public funds being provided to private network operators, the base case includes the gap for funding only one network.*

The $23.5 billion Investment Gap is based on the decision, for modeling purposes, that only one network will be funded in each unserved area. The reason for funding only one network is to keep the amount of public money required to a minimum.

Alternative approaches that would fund more than one network per area—for example, funding one wireline and one fixed-wireless network—would increase the total gap significantly for several reasons. First, the gap must include the costs associated with building and operating both networks. Second, because the two providers are competing for the same customers, each will have a lower take rate and, therefore, lower revenue.[8] While this lower revenue will be partially offset by lower variable costs—stemming from savings tied to costs like customer support and CPE—the net effect will be much higher costs per subscriber. For example, having both one wireline and fixed-wireless provider moves the Investment Gap up 45%, from $23.5 billion to $34.2 billion.

Exhibit 3-D:
Gap for Funding One Wired and One Wireless Network

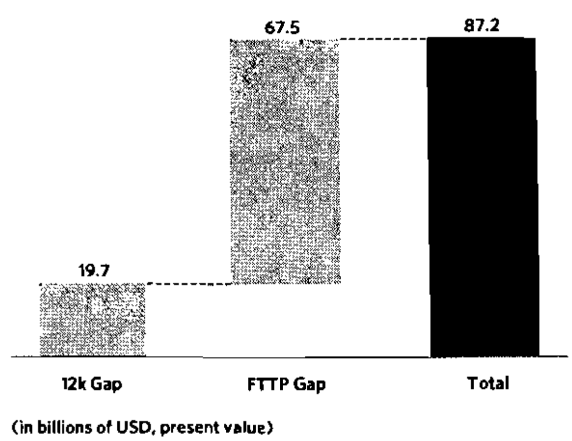


Funding two wireline competitors (instead of one wireline and one wireless) in these unserved areas has an even larger impact. Since only the first facilities-based service provider can make use of the existing twisted-pair copper network, the second facilities-based provider must deploy a more expensive, greenfield FTTP network (whether telco based or cable-based RFOG; see Chapter 4 discussion of FTTP and HFC). As shown in Exhibit 3-E, having two wireline providers in unserved areas shifts the investment gap to $87.2 billion.

While funding only one broadband provider in each currently unserved market leads to the lowest gap, this choice may carry costs of a different sort. In areas where a wireless provider receives support to provide both voice and broadband service, the incumbent wireline voice provider may need to be relieved of any carrier-of-last-resort obligations to serve customers in that area. In such a circumstance, it may be that only wireless operators will provide service in these areas. If, at some point in the future, the National Broadband Availability Target is revised in such a way that a wireless carrier can no longer economically provide service, a wireline provider may need to build a new, higher-speed network.

As noted above, competition impacts the take rate for each operator. In addition, we assume that competition leads to lower average revenue per user (ARPU). See Exhibit 3-F.

Exhibit 3-E:
The Cost of Funding Two Wired Networks



Since costs are calculated based on demand, reducing take rate will also reduce some costs. In particular, CPE costs are driven directly by the number of competitors. In addition, the cost of some network equipment, including last-mile equipment like DSLAMs, is sized according to the number of customers. This calculation will capture both the reduction in total cost and the increase in cost per user that comes from having fewer customers.

Exhibit 3-G shows the impact of competition on the investment gap for both 12,000-foot FTTN and wireless solutions. Remember that the base-case Investment Gap is calculated from a mix of technologies in markets across the country.[9]

Capture likely effects of disbursement mechanisms on support levels. *Decisions about how to disburse broadband-support funds will affect the size of the gap. Market-based mechanisms, which may help limit the level of government support in competitive markets, may not lead to the lowest possible Investment Gap in areas currently unserved by broadband—areas where it is difficult for even one service provider to operate profitably.*

A mechanism that selects the most profitable (or least unprofitable) technology in each area would minimize the overall size of the NPV gap. In highly competitive markets, market-based mechanisms, including reverse auctions, can play that role.[10] However, in unserved areas, where the economics of providing service are challenging, the impact of market-based mechanisms is less clear.[11]

Since the incremental economics of deploying broadband for each technology depend on the infrastructure that is already deployed, there may only be a single operator capable of profitably deploying a given technology in a given area. In these cases where there are no competing bidders with similar economics, the bidder with the lowest investment gap may not bid based on its economics but rather the economics of the next-lowest-gap technology. In other words, the lowest-gap provider may be in a position to set its bid to be almost as high as the next lowest-gap competitor. Due to this reality, we have calculated the gap based on the second-lowest gap technology, so that we do not grossly underestimate the gap in these areas.

The lowest-gap provider may not always be able to extract the highest level of support because it may have imperfect information about its competitor's economics, or fear that it does. However, we believe calculating the gap based on the second-lowest gap technology is conservative and will be closer to reality in these markets.

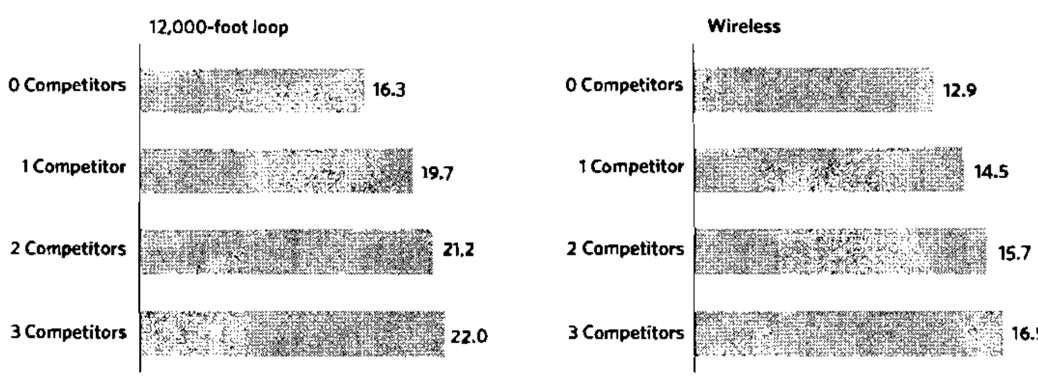
A calculation of the gap, assuming the lowest-cost operator provides service to all currently unserved areas, is $8.0 billion. The gap assuming the second-lowest-cost-gap provider in unserved areas is $23.5 billion. Since wireless appears to be the lowest gap technology in most unserved markets, and there is

Exhibit 3-F: Quantifying the Treatment of Competition

	Reduction in ARPU*	Reduction in Take Rate
0 Competitors	0.0%	0.0%
1 Competitor	4.3%	50.0%
2 Competitors	14.8%	66.7%
3 Competitors	28.2%	75.0%

* average revenue per user

Exhibit 3-G: Quantifying the Impact of Competition: Investment Gap by Number of Providers



(in billions of USD, present value)

a large disparity in cost between the first and second wireline competitor, excluding wireless from the analysis has a disproportionately large effect on the gap. As noted previously, the second wireline competitor in an area will not be able to take advantage of existing last-mile infrastructure and will, therefore, need to deploy a network connection all the way to the home. As such, the second wireline competitor has much higher costs than the first. If wireless is not part of the analysis and the second-lowest-gap provider uses wired technology, the gap moves up to $62 billion.

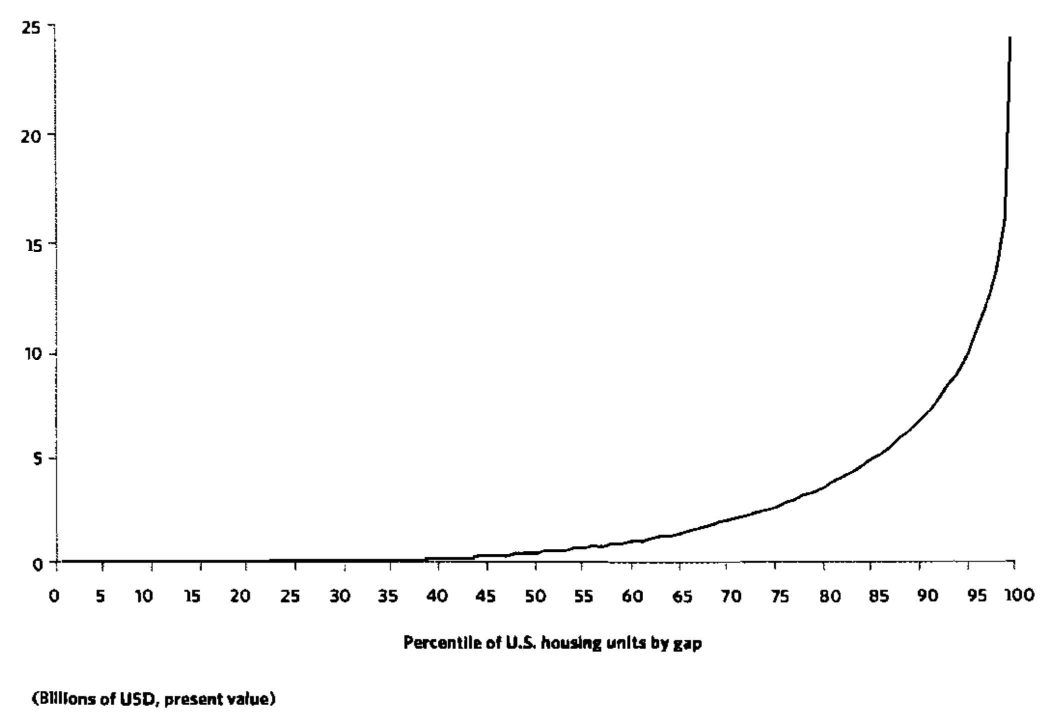
Focus on terrestrial solutions, but not to the exclusion of satellite-based service. *Satellite-based service has some clear advantages relative to terrestrial service for the most remote, highest-gap homes: near-ubiquity in service footprint and a cost structure not influenced by low densities. However, satellite service has limited capacity that may be inadequate to serve all consumers in areas where it is the lowest-cost technology. Uncertainty about the number of unserved who can receive satellite-based broadband, and about the impact of the disbursement mechanisms both on where satellite ultimately provides service and the size of the investment gap, all lead us to not explicitly include satellite in the base-case calculation.*

The $23.5 billion Investment Gap calculation estimates the gap to providing service to all housing units in the country with terrestrial service, either wired or wireless. While it seems likely that satellite will be an important part of the solution to the problem of serving the high-cost unserved, the current analysis includes only terrestrial solutions. Satellite has the advantage of being both ubiquitous and having a cost structure that does not vary with geography, making it particularly well suited to serve high-cost, low-density areas. Nevertheless, the focus of the model analysis remains on terrestrial providers.

While satellite is nearly universally available and can serve any given household, satellite capacity does not appear sufficient to serve every unserved household. In addition, the exact role of satellite-based broadband, and its ultimate impact on the total cost of universalizing access to broadband, depends on the specific disbursement mechanism used to close the broadband gap. The optimal role could be in serving housing units that have the highest per-home gap, or in ensuring that satellite can function as a ubiquitous bidder in a range of auctions. Moreover, while satellite firms can increase their capacity through incremental launches—noting that the current analysis includes all known future launches—the timing for bringing this capacity on-line may be problematic for closing the broadband gap, given the time required to design, build and launch a new satellite.

As noted in Exhibit 1-C, the most expensive counties have a disproportionately large investment gap. That same pattern—the most expensive areas drive a very high fraction of the gap—is repeated at smaller and smaller geographies. Exhibit 3-H shows the gap for all the unserved. The most expensive

Exhibit 3-H. Broadband Investment Gap, by Percent of Unserved Housing Units Served



3.5% of the unserved (250,000 housing units, representing < 0.2% of all U.S. housing units) account for 57% or $13.4 billion of the total gap. Were that group served by, for example, satellite broadband, even with a potential buy-down of retail prices, the gap could be reduced to $10.1 billion.[12]

Increasing the number of homes not served by terrestrial broadband leads to diminishing benefit, however. Moving the most expensive 15% of the unserved off of terrestrial options yields a gap of $3.8 billion. In other words, the savings from moving the first 3.5% off of terrestrial options ($13.4 billion) is more than twice the savings from moving the next roughly 12%.[13]

Support any technology that meets the network requirements. *Broadband technologies are evolving rapidly, and where service providers are able to operate networks profitably, the market determines which technologies "win." Given that, there appears to be little-to-no benefit to pick technology winners and losers in areas that currently lack broadband. Therefore, the base case includes any technology capable of providing service that meets the National Broadband Availability Target to a significant fraction of the unserved.*

The purpose of the Investment Gap calculation is not to pick technology winners and losers, but to calculate the minimum gap between likely private investment and the amount required for universal broadband. Therefore, the model is designed to calculate the profitability of multiple technologies to understand the cost and profitability of each.

The focus on profitability—on minimizing an area's investment gap—will lead to calculating the gap based on the least unprofitable mix of technologies. However, this is not an endorsement of any technology over another, or a recommendation for serving demand in any given area with a specific technology.

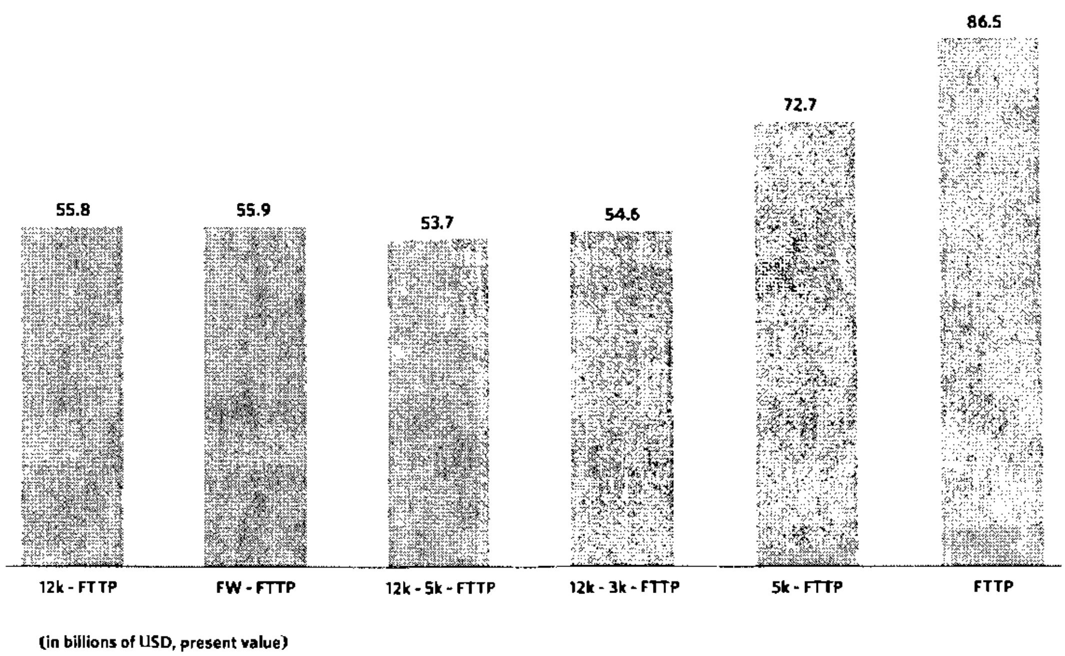
Over time, it may be the case that several technologies' capabilities improve, or their costs fall, more quickly than has been calculated—in which case, multiple competing technologies could profitably serve demand with a subsidy smaller than the one we calculate. Also, individual providers may have, or believe they have, the ability to provide service more cheaply.

Ultimately, the model assumes that any technology that meets the National Broadband Availability Target will be eligible to provide service.

Provide support for networks that deliver proven use cases, not for future-proof buildouts. *While end-users are likely to demand more speed over time, the evolution of that demand is uncertain. Given current trends, building a future-proof network immediately is likely more expensive than paying for future upgrades.*

The calculation of the $23.5 billion Investment Gap is focused on ensuring universal delivery of broadband over the next decade. However, given historical growth rates, it may eventually be the case that networks designed to deliver 4 Mbps downstream/1 Mbps upstream will be incapable of meeting future demand. In such a case, additional investments

Exhibit 3-1: Total Investment Cost for Various Upgrade Paths



beyond those included in the $23.5 billion gap calculation might be required. Whether historical growth rates continue is dependent on a variety of factors that cannot be predicted. If, however, we make assumptions about growth over time, we can estimate the impact on deployment economics.[14]

For example, the growth rate in the speed of broadband in recent years of approximately 20% suggests that broadband networks might be called upon to deliver speeds higher than 4 Mbps (downstream) and 1 Mbps (upstream) across the next decade or more. Simply put: if required speeds continue to double roughly every three years, demand will outstrip the capabilities of 4G and 12,000-foot-loop DSL.

To account for the current investments as well as these potential future investments, we calculated the lifetime cost of different technology upgrade paths. We evaluate the cost of deploying different technologies including the cost of future upgrades driven by the evolution in network demand, discounted to today. Although the lowest lifetime-cost technology will differ by market, it is possible to calculate the costs associated with various upgrade paths for the unserved areas as a whole, as shown in Exhibit 3-1.

To calculate the total cost for potential upgrade paths, a number of assumptions are necessary. The most important assumptions are the growth rate in broadband speed and the amount of salvage value remaining in a network when it is upgraded. For this calculation, the broadband speed is set to 1 Mbps (downstream) in 2010 and is grown at a rate of approximately 26% per year. When a network is upgraded, the capex required for the upgrade is reduced by the salvage value of the existing network - an upgrade that makes use of many of the assets of the original build will be cheaper. For example, fiber runs used to shorten loops to 12,000 feet will defray the cost of further loop shortening.

In this lifetime-cost calculation, an initial FTTP build-out is the most expensive because none of the initial capex is discounted. Regardless of which path is chosen, deferring the FTTP build-out lessens the total cost burden due to the time value of money. A number of the wireline upgrade paths have similar results. Again, the main differences between these options are salvage value and time value of money, given the assumed broadband growth rate.

This approach disadvantages fixed wireless relative to the other technology paths. Since the calculation only takes into account the ability to provide fixed broadband service, when the requirements for bandwidth outstrip the wireless networks' capability to provide economical fixed service, this calculation assumes that there is no value in wireless networks once they are overbuilt. In reality, and not captured in the calculation, wireless networks would have substantial salvage value in providing mobile service; i.e., once wireless networks can no longer meet the demands of fixed broadband, they can continue to generate value by delivering mobile services. This is in contrast to investments made in second-mile FTTN fiber that reduce the costs of future FTTP buildouts. However, despite this disadvantage, the fixed-wireless-to-FTTP upgrade path has the same total cost as the 12-kft-DSL-to-FTTP upgrade. Fixed wireless has lower initial capex; this lower capex offsets both higher opex for the wireless network and the cost savings from re-using fiber deployments made for a 12,000-foot-loop deployment. See, for example, Exhibits 4-W and 4-AK.

Note that this calculation is very sensitive to the growth rate assumed in required service speeds. If demand for speed grows only at 15% annually, the cost of the second upgrade path (fixed wireless upgraded to FTTP) drops by 23% as future upgrades are pushed out into the future and discounted further; these cost savings are partially offset by the higher opex of the fixed wireless network remaining in operation for more years. The cost of the first upgrade path (12,000-foot-loops upgraded to FTTP) drops even more, by 26%, as the FTTP investment is delayed.

KEY ASSUMPTIONS

Also implicit in the $23.5 billion gap are a number of major assumptions. In some sense, every input for the costs of network hardware or for the lifetime of each piece of electronics is an assumption that can drive the size of the Investment Gap. The focus here is on those select assumptions that may have a disproportionately large impact on the gap or may be particularly controversial. By their nature, assumptions are subject to disagreement; the section includes an estimate of the impact on the gap for different assumptions in each case.

- Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.
- The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.
- The average revenue per product or bundle will evolve slowly over time.
- In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.
- The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.
- Disbursements will be taxed as regular income just as current USF disbursements are taxed.
- Large service providers' current operating expenses provide a proxy for the operating expenses associated with providing broadband service in currently unserved areas.

Assumption: Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.[15]

This analysis takes the speed requirements of the National Broadband Availability Target as a given. That is to say that while there are ample analyses to support the target,[16] for the purposes of this analysis the required speed is an input. Below are some brief highlights from the research about speeds available and the impact of different assumptions about speed on the size of the financial gap.

Briefly, there are two independent but complementary approaches to setting the speed target for this analysis. The first approach examines the typical (median) user's actual speed delivered. As shown in Exhibit 3-J, median users receive 3.1 Mbps. In other words, half of all broadband snbscribers currently receive less than 3.1 Mbps. These data are from the first half of 2009; based on growth rates (as described elsewhere), the median will likely be higher than 4 Mbps by end of 2010. Updated data from a smaller sample show a median of 3.6 Mbps in January of 2010.

The second approach is to examine the use of applications by end-users to determine what level of broadband speed is required to support that level of use. Typical usage patterns today correspond to the "emerging multimedia" tier shown in Exhibit 3-K, with a growing portion of subscribers being represented best by the "full media" tier. Advanced Telecommunications Capability, including high-speed video, would seem to require at least the 4 Mbps "full media" tier.

While this suggests that speeds as low as 1 Mbps might be sufficient, it is worth noting that demand for broadband speeds has grown quickly, as shown in Exhibit 3-L. In fact, broadband speeds have grown approximately 20% annually since 1997.

Taken together, the median actual speed subscribed (3.1 Mbps, approaching 4 Mbps by year end) and the applications usage (1 Mbps but doubling every three-to-four years) suggest that a download speed of 4 Mbps will provide an adequate target with headroom for growth for universalizing purposes. Although not "future proof," this headroom provides some protection against rapid obsolescence of a high sunk-cost investment.

The calculations in this document focus on the National Broadband Availability Target. However, we built the tool with sufficient flexibility to calculate the gap across a range of target performance levels.

For example, if consumers demand only 1.5 Mbps, fewer housing units would be considered unserved (i.e., those with service above 1.5 Mbps but below 4 Mbps would be considered to have service). In addition, at the lower speed a lower-cost technology, DSL with 15,000 foot loops, becomes viable.

Should consumers demand higher speeds, in contrast, more people would be considered unserved. At the same time, only technologies capable of delivering higher speeds will be part of the solution set (e.g., 3,000-or 5,000-foot-loop FTTN, or FTTP).[17] See Exhibit 3-M.

Exhibit 3-J: Distribution of Users by Actual Maximum Download Speeds (Mbps)[18]

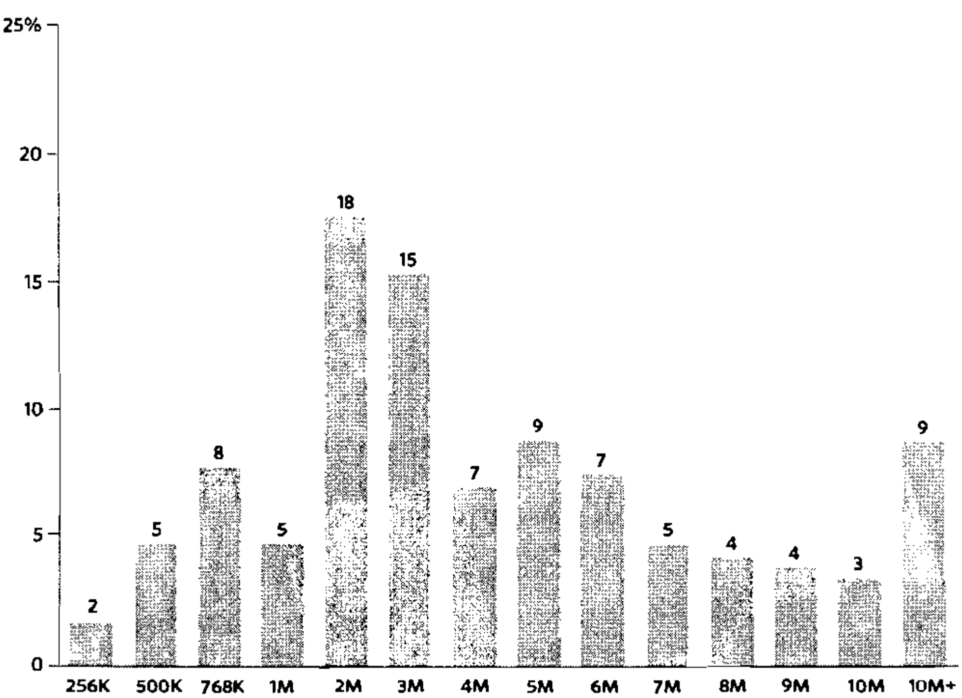


Exhibit 3-K: Actual Download Speeds Necessary to Run Concurrent Applications (Mbps)

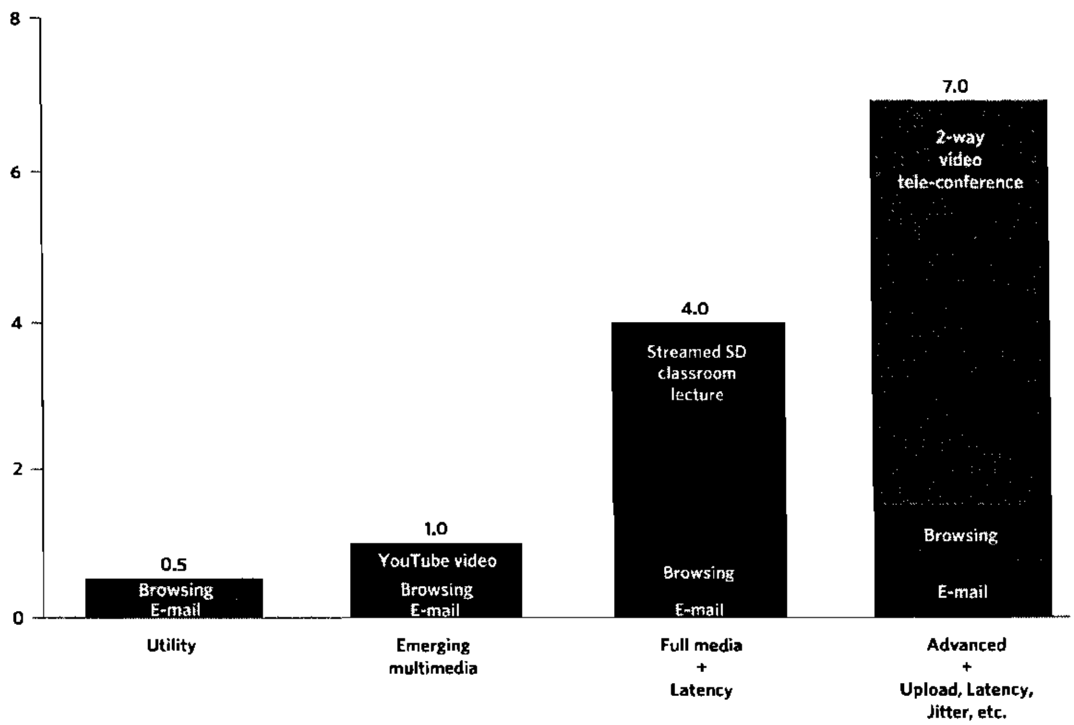
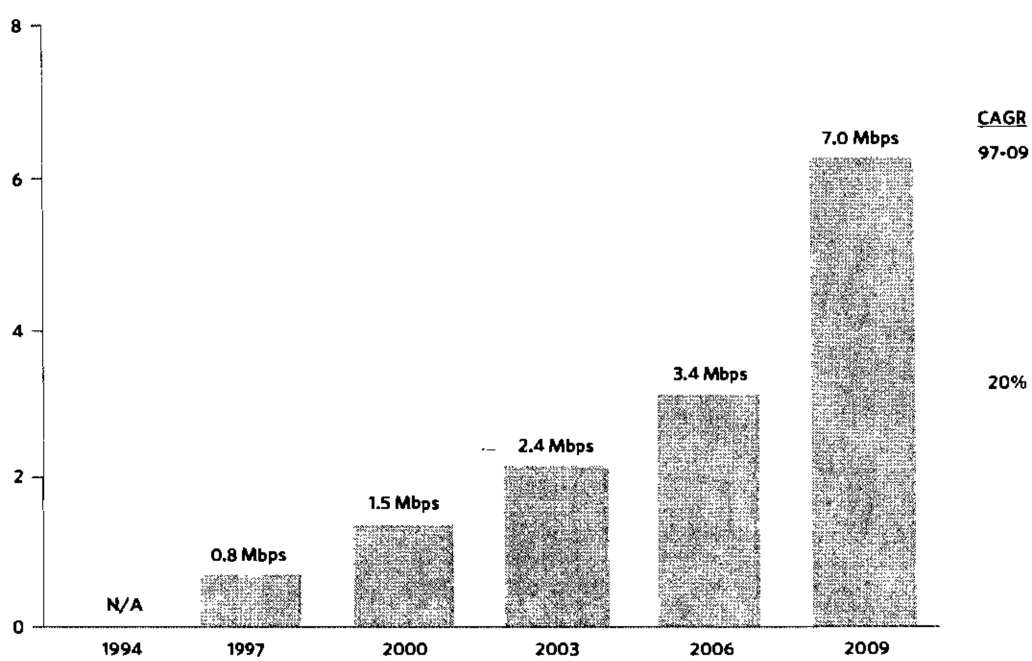


Exhibit 3-L: Typical (Median) "Up To" Advertised Download Speeds of Most Commonly Deployed and Chosen Consumer Household Broadband (Mbps)



Assumption: The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.

We need a measure of adoption over time to understand how quickly operators would attract customers—and accordingly revenue—to offset costs. Moreover, to be consistent with the granularity we have built into the model, it is necessary to make adoption sensitive to demographics.

In order to determine penetration rates of new broadband deployments in unserved areas, we choose to perform a combination of several statistical and regression analyses. Our primary data source is a table of home broadband adoption metrics from the Pew Internet & American Life Project. Since 2001, the Pew Research Center has conducted extensive, anonymous phone surveys on broadband adoption in the United States, breaking out responses by various demographics. Its surveys reveal positive and negative correlation factors between certain demographic characteristics and broadband adoption.[19] The Pew study noted the most significant factors, which are shown in Exhibit 3-N, in order of importance.

We obtained the results of the Pew study on broadband adoption covering 19 survey periods from October 2001 to November 2009. These data aggregate adoption percentages in each period by race, income, education level, rural/non-rural and overall.

Preliminary findings of the data revealed that the trends in broadband adoption matched those of standard technology adoption lifecycles. Our approach to this analysis is to understand the shape and characteristics of the Pew adoption curves in an attempt to incorporate the results into a mathematical model, by which future broadband adoption, or adoption in currently unserved areas, could then be forecast. We begin by examining a popular mathematical model used to forecast technology adoption: the Gompertz model.[20] Exhibit 3-O explains the highlights of the Gompertz model.

Exhibit 3-P illustrates the cumulative characteristics of the Gompertz model as a percentage of the installed base:

From an *incremental* standpoint, the period-to-period technology adoption unfolds as shown in 3-Q.

Note the characteristic "inflection point"—that is, the point at which the incremental curve is maximized and the cumulative curve flips over.[21] The inflection point should be considered the point where technology adoption reaches its maximum growth rate.

Our analysis of the Pew data consists of fitting each demographic data breakout (overall, race, income, age, education Level, rural/non-rural) into a Gompertz curve using a least

Exhibit 3-M: Dependence of the Broadband Investment Gap on Speed of Broadband Considered[22]

Broadband Speed (downstream)	Number of unserved HUs (millions)	Technology	Total cost ($ billions)	Investment gap per technology ($ billions)
1.5 Mbps	6.3	15,000-foot DSL	21.9	15.3
4 Mbps (base-case)	7.0	12,000-foot DSL	26.2	18.6
		4G wireless	18.3	12.9
6 Mbps	7.1	5,000-foot DSL	62.8	43.4
		3,000-foot DSL	76.9	57.3
50 Mbps	13.7	HFC/RFoG	124.9	85.0
100 Mbps[23]	130.0	FTTP	669.6	321.8

Exhibit 3-N: Broadband Take-Rate Drivers

Positively Correlated	Negatively Correlated
Income greater than $100K	Less than high school education
Income between $75K-$100K	Senior citizen (65+)
College degree or greater eduction	Rural
	High school degree only

Exhibit 3-O: Model for Technology Adoption

Model	Equation	When Used	Examples
Gompertz	$y=e^{-e^{-b(t-a)}}$	When substitution is driven by superior technology, but purchase depends on consumer choice.	Digital television, mobile phones

Exhibit 3-P: Modeled Cumulative Adoption

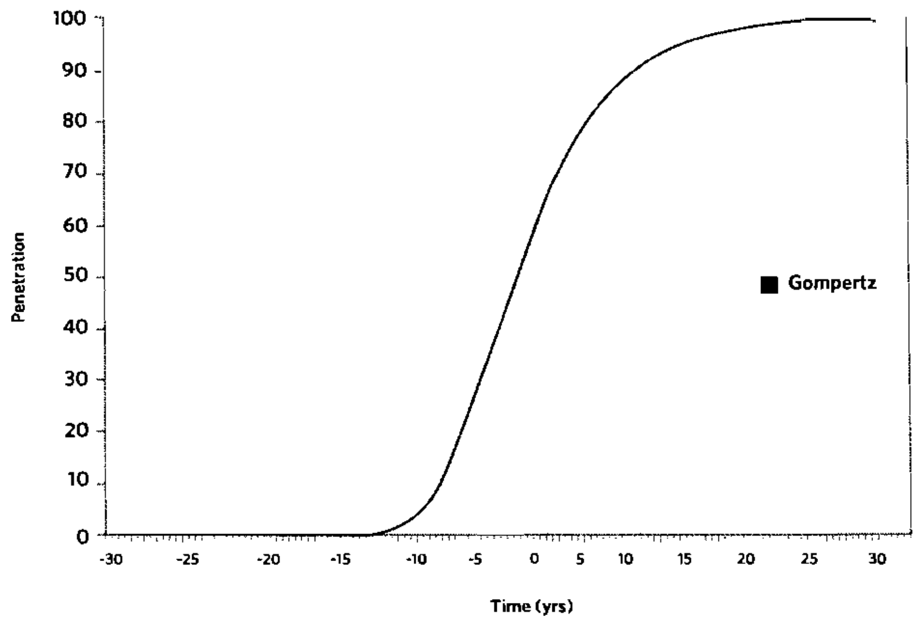
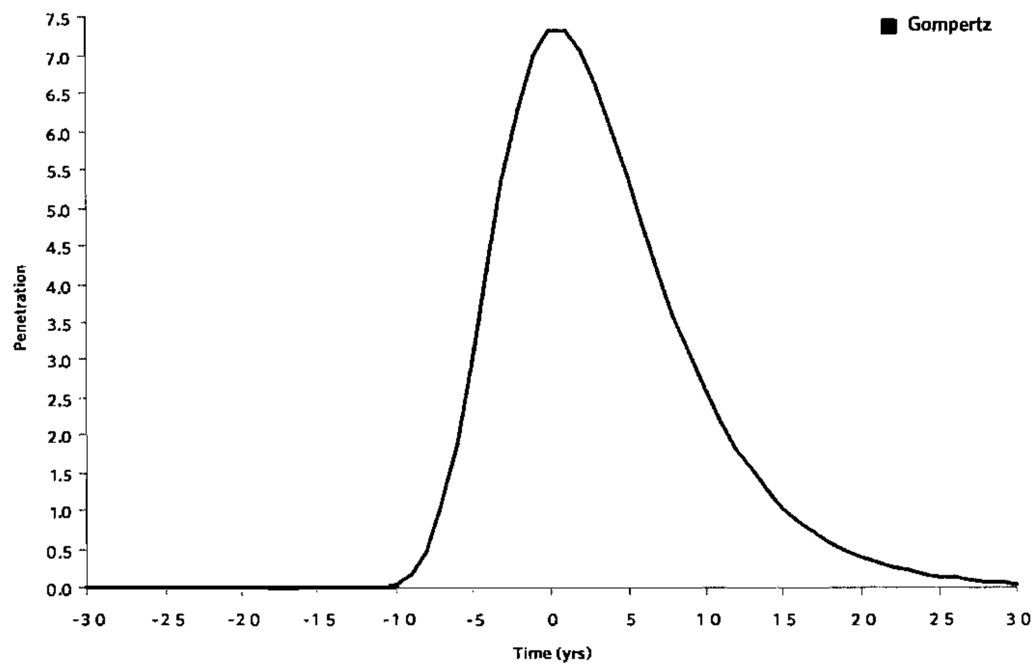


Exhibit 3-Q: Incremental Adoption



squares approach.[24] With a semiannual time period adjustment, the results indicated the Pew data segments can be fit on a corresponding Gompertz cumulative curve with very reasonable least squares accuracy. One such curve fit for a particular demographic (college graduates) is shown in Exhibit 3-R.

Our analysis provides us with Gompertz curves by each demographic in the Pew survey. However, consider that the Pew research starts with an arbitrary date of October 2001. This date does not presume the "start" of broadband in each surveyed area; it only represents the date at which surveys began. Therefore we must provide a time-based adjustment for every demographic curve. The solution we determine as most appropriate is to develop a series of demographic adoption curves relative to the overall adoption curve. Exhibit 3-S illustrates the relative Gompertz curve fits for every demographic segment. Here, the overall adoption curve inflects at zero on an adjusted time scale.[25]

Reinforcing the conclusions of the Pew study, the Income over $75K and College or Greater Education curves are farthest to the left (representing more rapid adoption relative to the mean), while the High School or Less, Rural and 65+ curves are farthest to the right (representing slower adoption relative to the mean).

It is worth noting that the Gompertz curves are based on adoption in areas across time, largely when broadband was first introduced—i.e., in greenfield areas. In brownfield deployments, however, builders are leveraging previous deployments to capture consumers who have already been educated on the benefits of broadband. We therefore allow for an additional time adjustment where brownfield builds are taking place.

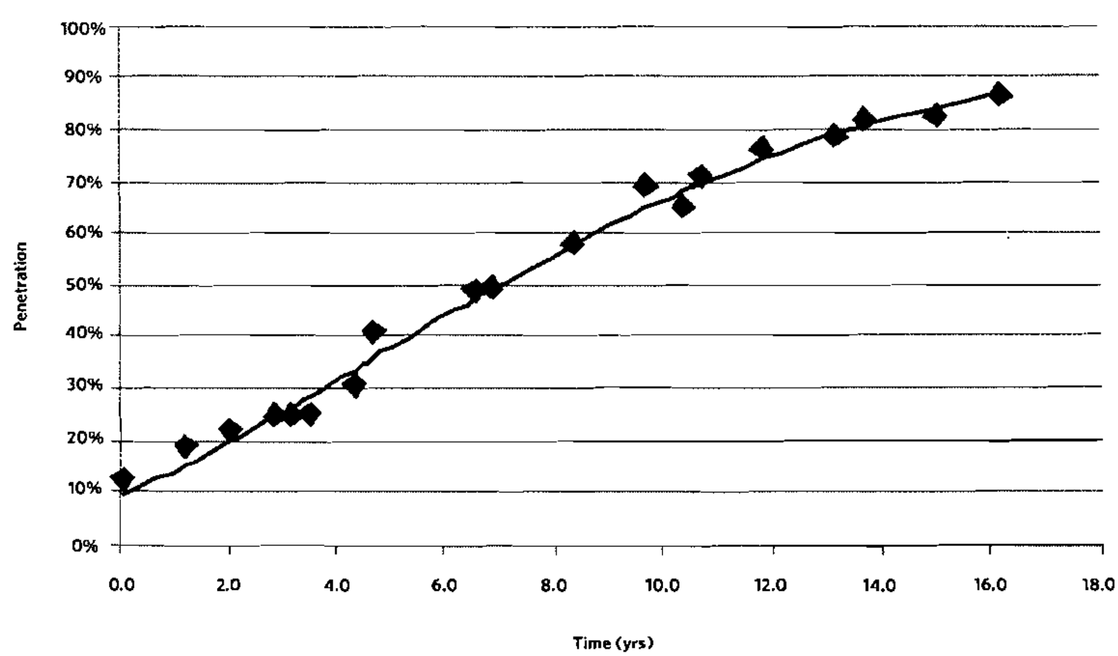
These results provide relative Gompertz curves by every demographic measured in the Pew study; however for a number of reasons, we chose to limit the prediction model to only the demographic factors with the largest positive and negative correlation to broadband adoption. While it would technically be possible to measure adoption changes across all the available demographics on the Pew study, it does not improve results meaningfully to do so—either the remaining demographics had minimal influence on broadband adoption, or the demographic data in question were not readily available at the appropriate demographic level.

The demographic variables we chose to predict broadband adoption are the following:

- Income greater than $100K
- Income between $75K - $100K
- College degree or greater education
- Senior citizen (65+)
- Less than high school education
- Rural
- High school degree only

Using the Gompertz coefficients for each demographic, combined with demographic data at the census block level,[26] we can build Gompertz curves for every census block in the nation. To build these custom curves, we weight the demographic Gompertz

Exhibit 3-R: Broadbond Adoption Curve



coefficients (a and b) by the incremental demographics prevalent in the area. For example, if the demographics within the overall curve show 18.5% of households have incomes above $100K, but a particular census block contains 20% of households with over $100K income, each "Over $100K" Gompertz coefficient would be weighted by the incremental difference (20% – 18.5% = 1.5%) and added to the overall Gompertz coefficient. By summing up the weightings off each significant variable, our Gompertz equation for each census block would take shape.

The additional step in forecasting broadband penetration rate is to determine how to factor in a brownfield effect, if any, into the census block time coefficient (a). If the census block is revealed to have a prior broadband deployment, the census block curve would be shifted left a designated number of periods. The number of periods to shift is held constant across all brownfield deployments.

The final step of developing the census block curve is to determine where to set the inflection point. The zero point on the horizontal axis scale is intended to represent the point at which the overall curve inflects, but the time at which the scale hits zero must be determined. We initially chose this scale to be two years from the start of deployment; essentially, the overall broadband adoption would reach its maximum growth rate in 24 months. To account for the initial mass influx of customers in the first 24 months, we chose to start with zero subscribers at initial deployment, then trend towards the number of subscribers at 24 months by dividing them into four equal 6-month periods of subscriber adoption. After 24 months, the penetration rates reflected in the Gompertz curve would be in effect. The selection of an inflection point, while initially set at 24 months, is one that can potentially be re-examined and adjusted as needed.

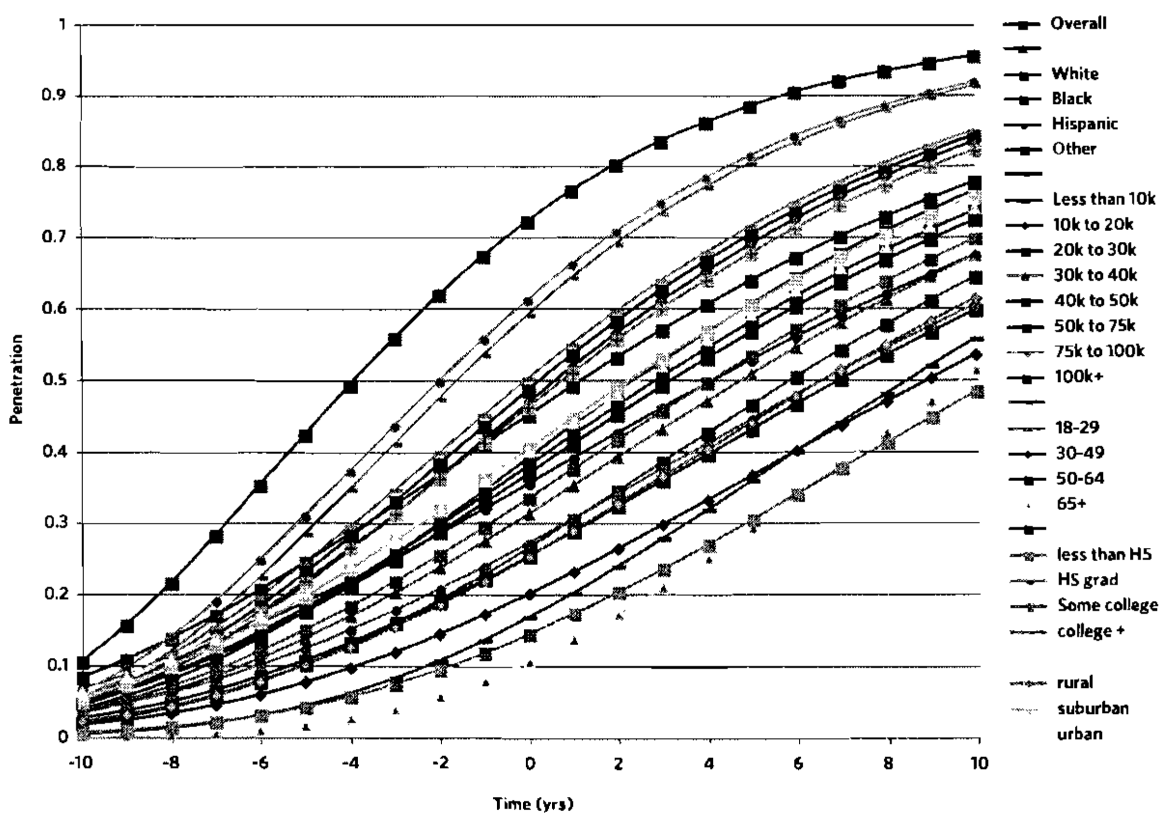
Additional factors

The resulting census block penetration rate determines the standard broadband adoption rate for that census block. It does not, however, factor in the subscribers of related incremental services (e.g., voice, video), the effect of bundled services or the stratification of tiering (basic vs. premium). To account for each of these, we developed factors from which we could adjust the baseline number of expected broadband adopters in every census block. Each factor is discussed below.

Scaling factor

A scaling factor, in this instance, refers to a multiplying factor developed to predict voice and video subscribers by technology (DOCSIS, FTTP, FTTN and Fixed Wireless) based on the number of broadband subscribers.[27] The presumption is that

Exhibit 3-S: Gompertz Curves for Broadband Take Rate With Demographics



each technology exhibits a constant and unique relationship between broadband subscribers and subscribers to other services like voice and video. In other words, if one knows the number of broadband subscribers for a particular technology, one can predict the number of voice or video subscribers as well.

Bundling percentages

Customers who subscribe to broadband services belong to one of two groups: those that purchase a la carte, or those that purchase as a bundle. Industry analysis confirmed that the relationship between the two subscriber bases is relatively constant for each technology.[28] Using these data, we developed a "bundling" percentage based on the broadband subscribers, in order to arrive at the number of bundled subscribers. The number of bundled customers can then be subtracted from the total number of voice and video subscribers to arrive at the number of a la carte subscribers for each. The percent of users who take bundles for each technology is shown in Exhibit 3-T.

Tiering percentages

Tiering, in this case, refers to the tiered services offered by carriers. To limit unneeded complexity, we limit the number of tiers in the model to two levels: a basic introductory level of service and a "top-shelf" premium service. These low/high tiers are applicable to video (for example, basic vs. premium cable), data (entry-level vs. top speed) and even bundles. Using industry data we are able to develop percentages by technology that break out the respective service subscribers into low-end and high-end tiers.[29] These "tiering" percentages are then applied to the number of broadband, video and bundled subscribers to arrive at low-tier subscribers and high-tier subscribers for each.

Take-rate sensitivities

The Gompertz curve for data product penetration is driven by the demographics at the census block group level and is independent of changes in price. Treating broadband data products as relatively demand inelastic is consistent with the recent findings by Dutz et al (2009), who estimated own-price elasticity for broadband in 2008 to be -0.69.[30] Despite these findings, it is important to understand the impact of adjusting the market penetration levels up and down to show the sensitivity of take rate on costs and revenues. Exhibit 3-U illustrates the impact on the overall private investment gap at different market penetration levels. Note that the bulk of the difference in the gap comes from changes in revenues rather than changes in costs.

Exhibit 3-T:
Assumed Percentage of Customers with Bundles

Data	Percent with Bundles
FTTN	65% (data, voice and video where appropriate)
Wireless	98% (data and voice)
Cable	40% (data, voice and video)
FTTP	67% (data, voice and video)

Assumption: The average revenue per product or bundle will evolve slowly over time.

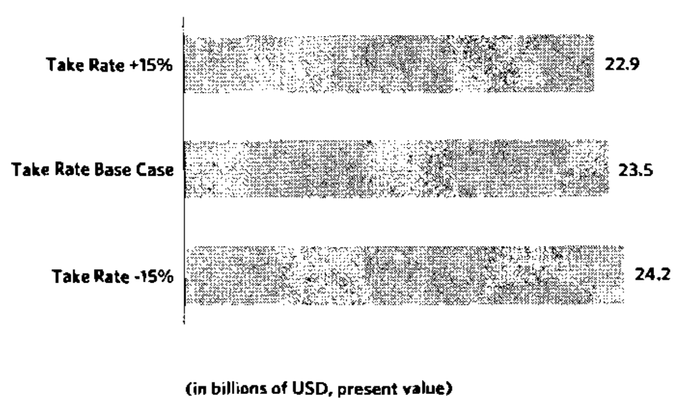
ARPU forecast

In order to develop a close approximation for ARPU, two main issues must be resolved. First, each product category (data, voice, and video) must have an individual ARPU value and the product bundle must also have an ARPU value. An additional level of sophistication, customer segmentation, is added by including a low and high version of the data, voice, video, and bundle product categories. Second, the current disparity in pricing between telco and cable voice products must be resolved.

The complexities of the market create additional challenges. Using estimates of current revenue streams may overestimate, perhaps significantly, the revenue available in the future. Both voice ARPU and the number of residential lines are under pressure from a confluence of technical evolution and new competitive models.[31]

In real terms, the average price of a residential access line has fallen since 1940 by about 50%.[32] Simultaneously, interstate and international per minute revenues have

Exhibit 3-U:
Sensitivity of Gap to Take Rate



dropped steadily since 1985, even in nominal dollars.[33] These trends are the result of competition from wireless and cable, capacity expansion and the advent of Voice-over-IP (VoIP). As these drivers (especially VoIP growth) accelerate, voice ARPU is expected to continue to decline. To account for this market price shift, revenue attributed to incremental voice customers for telcos is set equal to the ARPU for a similar cable VOIP product.

Video ARPU may also be challenged in the years to come. The FCC's cable pricing survey indicates video ARPU has increased year-over-year since 1995 with 55-60% of that increase attributable to programming cost.[34] Cable's video business was protected from competitive threats for much of this historical period, which may change with the recent rise of telco, satellite and "over-the-top" (OTT) or Internet video offerings like Hulu and Netflix. Just as wireline telephone revenues and margins began to shrink after Congress mandated competition in the local telephone market in 1996, it is possible that video ARPU will come under pressure going forward.

Despite these downward trends in per-product ARPUs, annual spending on voice and video services has remained nearly constant as a percentage of total household spending. The annual Consumer Expenditure Survey by the Bureau of Labor Statistics and the FCC's Cable Industry Prices report shows that aggregate annual household expenditure for telephone (wired and wireless) and video has remained between 3.0% and 3.4% of total expenditures between 1995 and 2007.[35]

It is unclear how these trends will play out over time and whether a rise in data-services ARPU will offset expected erosion in voice and video ARPU. The ARPU assumptions in the model are based on a moderate view, where ARPUs evolve slowly over time. Model ARPUs are shown in Exhibit 3-V; note that these ARPUs are the levelized figures across the study time period.

Finally, a number of products either do not yet exist or do not have a long pricing history (e.g. fixed wireless LTE data services). While the average price per minute for a mobile voice call continues to fall or be replaced by unlimited plans, industry forecasts show continued growth in mobile data revenue. As more and more consumers begin using mobile devices as broadband connections, the pricing dynamic between voice and data may shift. While this shift may take place, ultimately we believe the total ARPU per customer as noted above will remain relatively flat.

Drawing on the data and forecast methodology described above, we assume the ARPUs described in Exhibit 3-V.

ARPU sensitivity

Given the product dynamics and uncertainty around the evolution of ARPU in the future discussed above, we conducted a number of sensitivities for overall revenue to estimate the impact of a change in ARPU on the investment gap. Exhibit 3-W shows the change in the amount of support required when the ARPU is scaled up and down by a number of percentages.

Assumption: In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.

The cost of wireless deployment varies greatly based on terrain due to reduced propagation in areas with significant elevation change. Simply put: more mountainous areas are harder and more expensive to serve, a fact reflected in the existing wireless coverage of mountainous areas.

General principles for the design of a wireless network (discussed further in the wireless section of Chapter 4) can be used to calculate cell size in areas without geographic interference for a given frequency and required bandwidth. Determining the actual cost of a wireless deployment would require a tuned propagation model.[36] We take an approach somewhere between applying the general principles of wireless network design and a tuned propagation model to take into account the impact of terrain on cell sizes and therefore costs.

To try to capture some of these terrain dependencies, the model adjusts the cell size based on the ruggedness of the terrain. Flat areas are assigned larger cell radii, and therefore lower costs, while hilly and mountainous areas have smaller cell radii and higher costs.

Exhibit 3-V: Summary of Modeled ARPUs

		Data		Video		Bundle	
	Voice	Low	High	Low	High	Low	High
Telco	33.46	36.00	44.00	50.00	80.00	95.57	130.00
Cable	33.46	36.00	44.00	50.00	80.00	95.57	130.00
Wireless (4G footprint)	33.46	36.00	36.00	-	-	56.00	56.00
Wireless (non-4G footprint)	51.96	43.00	43.00	-	-	80.00	80.00

We are able to take into account the different costs across a variety of terrains by first calculating the cost associated with serving each populated census block in the country with two-, three-, five- and eight-mile cell radii—in other words, the total cost of a nationwide network build is calculated for each cell radius, with costs allocated down to census blocks. Census blocks are then aggregated into census tracts.

We then calculate the standard deviation of elevation in each census tract. See Exhibit 3-X to see the variation of elevation across the country.

Areas with high standard deviations have large elevation variability and require smaller two-mile cell sizes; flatter areas have lower standard deviations and are assigned larger cell sizes. See Exhibit 3-Y, which shows cell-size overlaid on the terrain map. The areas with largest cell sizes, indicated in dark blue, are primarily along the coasts and the Mississippi plain. Smaller cell sizes, in green and yellow, are in mountainous areas of the East (along the Appalachians and Berkshires) and in the West.

More detail about cell radii and the impact of wireless model assumptions can be found below in the section on wireless technology.

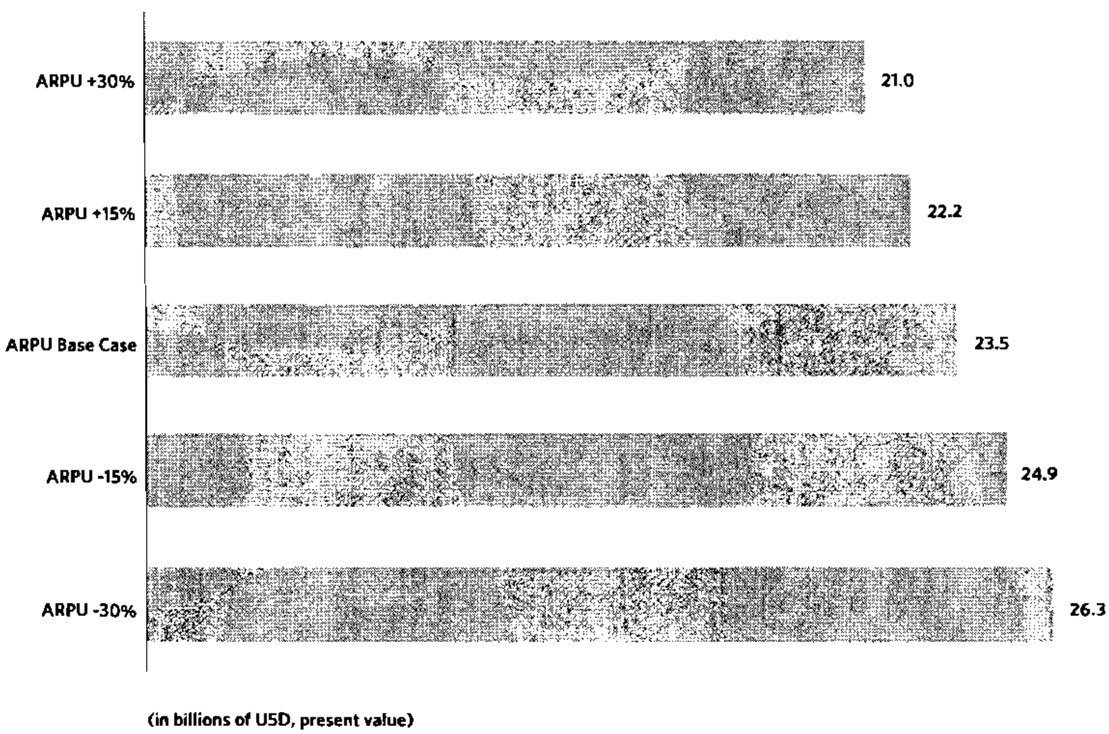
Exhibit 3-Z illustrates the results of making different assumptions about what cell sizes are appropriate in what kinds of terrain. The graph includes the cost of the wireless build; the gap associated with that build; and the overall gap, which because it is driven by the second-lowest-cost technology, varies by less than 10%. In fact, we find that the percentage of unserved housing units served by wireless drops very little (to 89.1% from 89.9% in the most extreme case tested), thus explaining the relatively small impact terrain classification has on the overall investment gap. The analysis and assumptions that led to Exhibit 3-Z are discussed more fully in Chapter 4 (leading up to Exhibit 4-Y).

Assumption: The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.

The presence of commercial wireless 4G buildouts in areas unserved by terrestrial broadband today can have a major impact on cost and the investment gap. Such commercial buildouts are driven by each company's strategic plans, meaning that the builds could be profitable on their own (i.e., that mobile revenue tied to that location exceeds the cost of deployment), or could be important for other reasons (e.g., to differentiate based on network coverage or to reduce dependence on roaming partners).

Regardless of why such networks are built, their presence has a dramatic impact on local wireless-network economics, since the costs of providing fixed-broadband service will be lower for a service provider that already operates a network that provides mobile services. At issue is the fraction of the total cost required to upgrade commercial buildouts designed

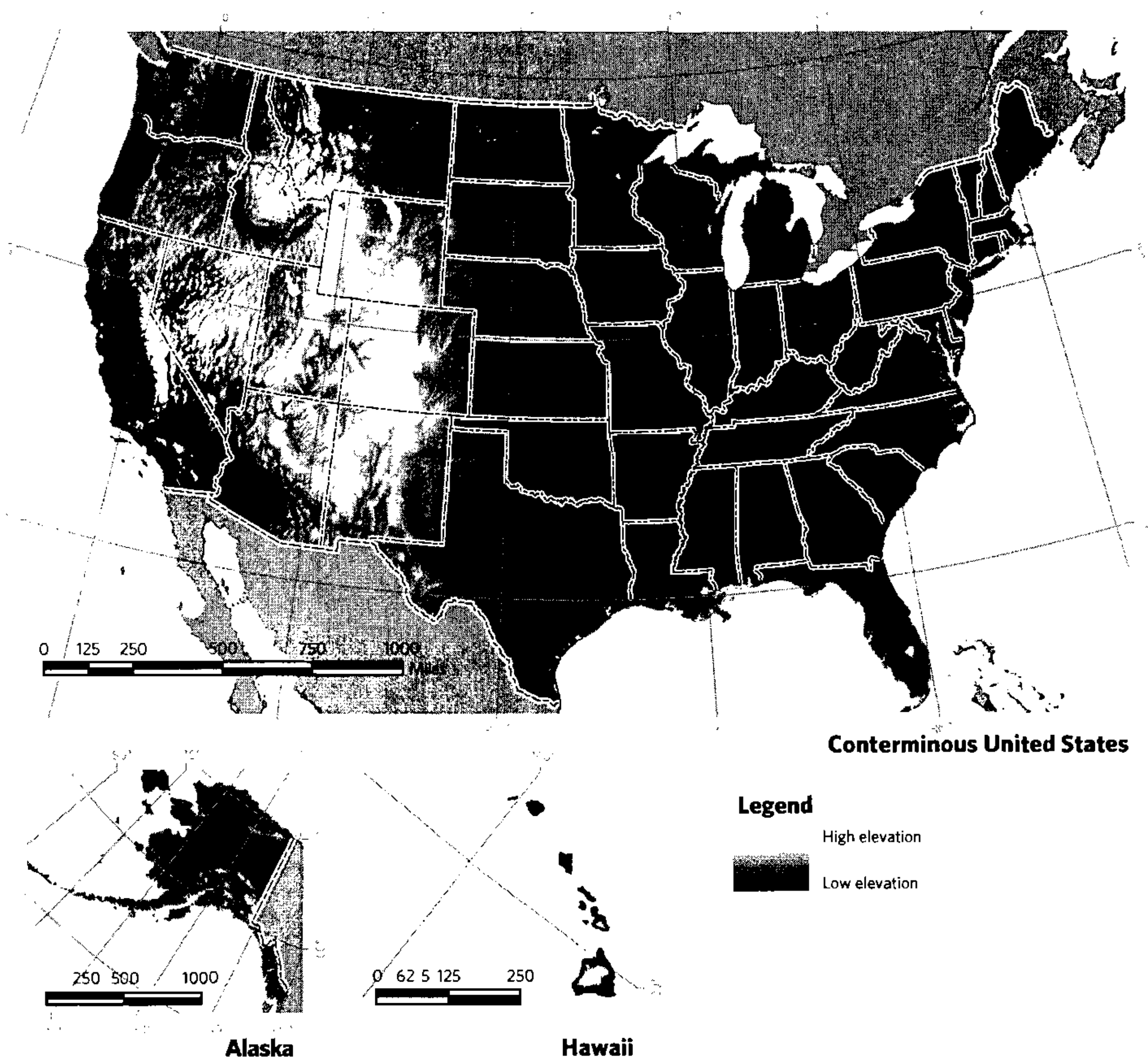
Exhibit 3-W: ARPU Sensitivity



to provide 4G mobile service to the signal density required to provide fixed service at 4 Mbps downstream/1 Mbps upstream. In addition, the operator would have some amount of revenue even without the fixed-network upgrade. Consequently, we estimated both incremental cost and revenue.

To estimate incremental costs, we allocate costs between the fixed and mobile businesses. While both fixed and mobile businesses benefit from improvements to their shared infrastructure, the fixed business drives many of the costs. Fixed service drives more traffic per connection and, as will be

Exhibit 3-X:
Elevation Across the U.S.



discussed later in the wireless portion of Chapter 4, network requirements for fixed broadband service lead to the need for more and smaller cells.

Therefore, the model allocates costs by the amount of traffic driven by fixed and mobile service. The average mobile user with a broadband handset used 65 MB[37] of capacity per month in 2009, while the average fixed user consumed 9.2 GB;[38] however, mobile data usage per user is currently growing at 84%,[39] while fixed usage per user is growing at "only" about 30%.[40] Assuming that there are two mobile users for every fixed

Exhibit 3-Y:
Estimated Average Cell Size in Each County and Terrain